Intensively Monitored Watershed Restoration Project
Bridge Creek Workplan-Draft

Photograph: A reach of Bridge Creek that has aggraded behind a large beaver dam and flooded a terrace, greatly expanding the riparian area. Just upstream is a similar reach without a beaver dam and a terrace covered with sagebrush.

Prepared for the Bonneville Power Administration

By:
NOAA Fisheries, Northwest Fisheries Science Center 2725 Montlake Blvd. E Seattle WA 98112.
Contacts: Chris.Jordan@noaa.gov & Michael.Pollock@noaa.gov

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Introduction

Under the U.S. National Oceanic and Atmospheric Administration Fisheries 2000 and 2004 FCRPS Biological Opinions (BiOps; NMFS 2000, 2004), mitigation for the mortality resulting from the Federal Columbia River Power System (FCRPS) has been focused on tributary habitat restoration. The Tributary Federal Research, Monitoring and Evaluation Program, as described by the BiOps, is responsible for evaluating whether the implemented restoration actions have achieved their assumed benefits (Jordan 2003). A network of Intensively Monitored Watershed (IMW) studies has been initiated throughout the region to evaluate population level responses to large-scale restoration efforts, one of which is proposed to be the Bridge Creek Watershed, a tributary to the John Day River (Bilby et al. 2004; Bilby et al. 2005; PNAMP 2005). IMWs are whole watershed restoration projects implemented in an experimental fashion to maximize the ability to detect habitat and fish responses (Bilby et al. 2005; Roni et al. 2005; Reeve et al. 2006). If these large scale manipulations with intensive monitoring do not result in detectable population-level responses, then it is unlikely that smaller scale, less intensively monitored projects ever will. Thus, IMWs are a necessary approach to evaluate the effectiveness of restoration efforts and strategies before implementing them more widely

We propose to restore large sections of instream and riparian habitat along the lower 31 km of Bridge Creek sufficient to cause a population-level benefit to the steelhead (*Oncorhynchus mykiss*) that use this system. Bridge Creek is a straightened, incised stream that is disconnected from its floodplain and has lost most of its alluvial groundwater storage capacity and riparian vegetation. Stream temperatures are high in the summer due to both a lack of riparian cover and reduced based flows from the loss of alluvial groundwater storage. This project seeks to cause aggradation of the incised stream trench to restore floodplain connectivity and increase both groundwater storage capacity and the extent of riparian vegetation (see overview of causes and effects of incision in Appendix 1). We propose to do this by installing a series of instream structures designed to assist beaver (*Castor canadensis*) in the construction of stable dams that can trap sediment and aggrade the stream bed. The few existing beaver dams in Bridge Creek are currently trapping sediment, but lack sufficient structural support and dam-building materials to construct stable dams. We also propose to plant riparian areas with cottonwood and other woody vegetation to provide a boost to the long-term food and dam-building supplies for beaver. These restoration activities will accelerate natural recovery rates of the processes that create and maintain steelhead habitat and will substantially increase steelhead productivity within the drainage.

We are employing focused monitoring efforts to enable us to assess the effects of our proposed restoration efforts on steelhead populations. Bridge Creek is an Intensively Monitored Watershed (IMW) where stream physical habitat conditions and steelhead use have now been monitored intensively for several years. We will utilize and expand upon these ongoing data collection efforts to provide pre-project conditions and continue to monitor to assess post-project changes to both steelhead populations and physical habitat. We will also use several tributaries to Bridge Creek and an adjacent watershed (Murderers Creek) as controls against which to compare changes in steelhead populations. The monitoring efforts are designed to be able to detect a steelhead population-level increase resulting from the restoration actions.

Bridge Creek

The Bridge Creek subbasin is a 710 km^2 watershed draining directly into the lower John Day River. Bridge Creek and its tributaries are utilized by a run of Middle Columbia steelhead that are part of the ecologically distinct Lower John Day population which occupies the lower, drier Columbia Plateau ecoregion within the John Day Subbasin. This population is listed under the Endangered Species Act (CBMRC 2005, p. 75). The John Day Subbasin Plan (JDSP) has designated Bridge Creek as a priority watershed for restoration because its salmonid production and abundance potential is high (CBMRC 2005, pp. 83, 249).

We chose Bridge Creek for this restoration project because it is a deeply incised stream in the semi-arid portion of the Columbia River Basin that contains steelhead and has cooperative, fish-friendly landowners along most of its lower mainstem and lower tributary reaches. Bridge Creek would also be the only IMW in a semi-arid climate where incision is common, and thus presents a unique opportunity to quantify the benefits of our restoration efforts (see discussion of the IMW concept in Appendix 2). Analysis of the John Day and other subbasins in the interior Columbia River basin suggest that incision is a widespread phenomenon in the lower elevation streams of the CRB, affecting as much as half of all the fish bearing streams in a watershed (e.g. see Figure 1, from Beechie and Pollock, in review). To date, very few watersheds in the semi-arid regions of the Columbia River basin have had focused restoration efforts even though semi-arid lands comprise much of the basin. This is unfortunate, because the remnant steelhead populations in these lower elevation streams are most susceptible to climate change and stream dewatering and would benefit substantially from large-scale restoration actions. Restoration of these incised, lower elevation streams is needed before the remnant steelhead populations in them are completely extirpated. This project will demonstrate how such streams can be restored and will monitor and demonstrate the benefits to steelhead.

This project will be conducted in collaboration with other efforts in the greater John Day Basin. ODFW is currently conducting a basin-wide monitoring program to describe steelhead and salmon population and their habitat status and trends. In addition, ODFW is evaluating distributional patterns of juvenile salmonids and their relationship with habitat characteristics. Thus, a context is provided for the results of this large scale habitat restoration program within the rest of the Lower John Day steelhead population. In return, the Bridge Creek IMW high resolution information will help identify important steelhead life history strategies and their relationships with habitat, as well as verify monitoring techniques that cannot be tested at the scale of the John Day Basin.

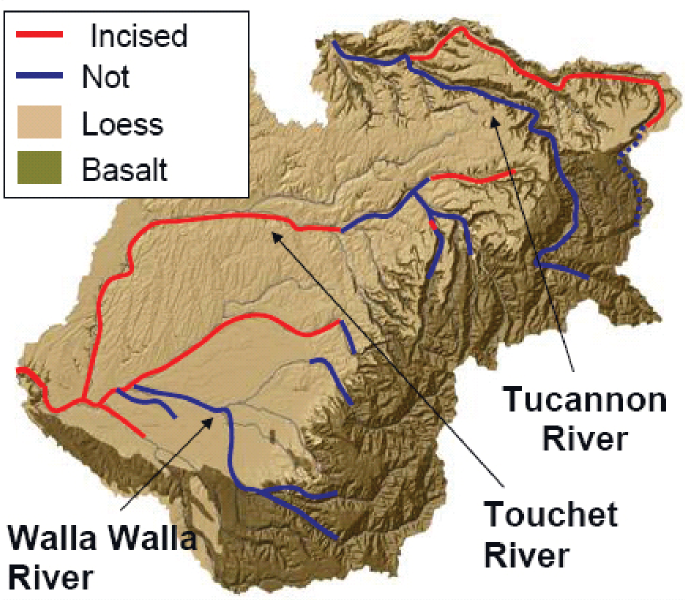

Figure 1. Widespread incision occurs throughout the Columbia River basin. This figure shows that More than half of the major streams in the Walla Walla, Tucannon and Touchet River systems are incised.

A process-based restoration approach

The physical goal of our restoration actions is to reinitiate the natural processes that historically retained sediment and allowed the stream bed to aggrade (Elmore et al. 1994). Such aggradation will reverse the negative impacts of incision that have occurred in the past 150 years (Peacock 1994). Specifically, aggradation will raise floodplain water tables and lead to increased summer streamflows, decreased stream temperatures, a narrower and more sinuous stream channel, and a vastly expanded riparian forest, as has been observed elsewhere (Reviewed in Pollock et al 2003). The Ecosystem Diagnostic and Treatment (EDT) model identifies habitat quantity, temperature, sediment load, habitat diversity and flow as limiting factors in Bridge Creek (CBMRC 2005, p. 83). Thus, when we initiate the process of aggradation, it will trigger a series of positive feedback loops that restore other biological and physical processes that currently limit this population (Figure 2).

Presently, aggradation is already occurring to a limited degree behind reaches where a few beaver have constructed dams, a process well documented in other semi-arid landscapes and elsewhere (Scheffer 1938, Meentemeyer and Butler 1999, McCullough et al. 2005). Some of the beaver dams on Bridge Creek have backfilled with sediment, raising the stream bed and allowing for riparian vegetation such as willows to colonize (Figure 3).

This process has locally elevated the stream bed by as much as 1.5 m in some places, but more typically by less than 0.5 m. Unfortunately, many dams fail before the upstream sediment wedge and dam can be stabilized by riparian vegetation. Dams appear to fail primarily because of the lack of large diameter woody vegetation (e.g. willow and cottonwood stems) and anchoring structures (e.g. large wood or boulders) to provide sufficient strength to withstand high flows (M.

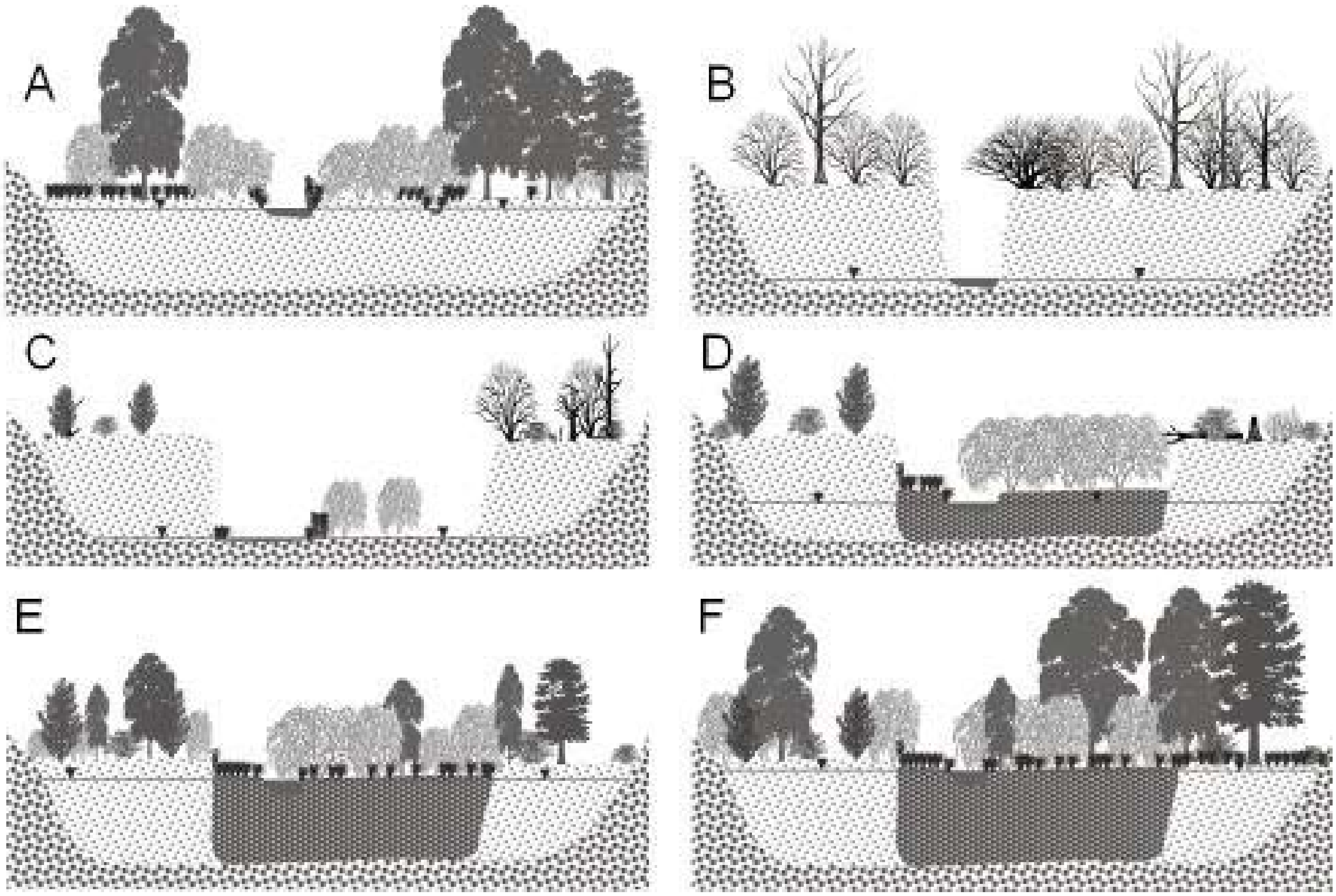

Figure 2. Conceptual diagram of incision and filling cycle in semi-arid environment such as the interior Columbia River basin. A) A fully aggraded stream connected to its floodplain and a water table near the floodplain surface B) Incision is triggered, usually by a change in land use practices that result in increased stream power. The water table lowers, resulting in the death of riparian vegetation. The channel is confined to a narrow trench. C) Eventually, the incision trench widens as the channel develops meanders, and a narrow floodplain establishes with a greatly diminished riparian area. Xeric plant communities dominated by juniper and sagebrush develop on the former floodplain D) Floodplain vegetation such as sedges and willows trap sediment during high flows, and the developing meandering pattern of the stream lowers the stream gradient. Within the incised trench, aggradation begins to occur and the water table rises. E) Over time, continued aggradation begins to reconnect the stream to its former floodplain, and the water tables continue to rise. During this period, plant diversity is high because both xeric and riparian species are present. F) As conditions become more favorable to riparian species, the xeric species die out and riparian plant biomass continues to increase.

Pollock, personal observation).

The Bureau of Land Management has been monitoring the location of beaver dams in Bridge Creek for almost two decades and assessing the improvement in riparian condition as a result of these dams (Rick Demmer BLM, manuscript in review). Demmer's data demonstrates that extensive willow colonization occurs upstream of beaver dams, and it also demonstrates the extremely ephemeral nature of most of the beaver dams that are constructed in this system. While elsewhere, dams typically last 1-3 decades, in Bridge Creek, the majority of dams last one year or less (Figure 4).

The short life of these beaver dams is due to the high stream power typical of entrenched streams like Bridge Creek. By necessity, many of the dams are built in narrow, entrenched reaches that carry the full force of flood waters-there is no accessible floodplain to dissipate the force of the water during high flows. This problem is further compounded by the lack of large diameter building material for the beaver to build durable dams. Along much of lower Bridge Creek, there is a thin band of small diameter willows (< 2" dbh) with few trees or shrubs greater than 4" in diameter. Where available, beaver will also utilize obstructions such as boulder or large pieces of wood (i.e. large woody debris) to anchor their dams and provide added stability (MacCracken and Lebovitz. 2005).

Given the paucity of available construction materials and support anchors, the beaver in Bridge Creek have made remarkable progress in a few

Figure 3. View of an aggraded reach upstream of a 1.5 m high beaver dam on Bridge Creek, Oregon. The pond has almost completely backfilled with sediment. Willows, cattails and other riparian vegetation have colonized the new surface. Additionally, willows have recently replaced sagebrush on the adjacent terrace where water tables have risen to within 0.5 m of the surface. The dam is just beyond the patch of open water in the upper left of photograph..

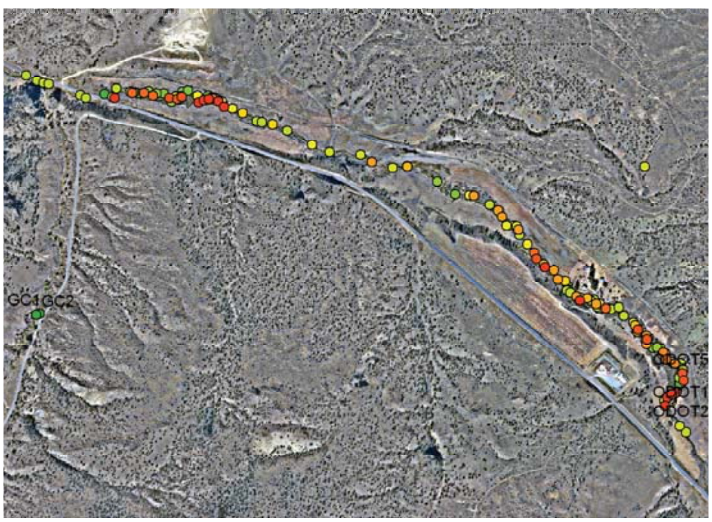

Figure 4. Location of 164 beaver dams observed between 1988-2004 along a 5 km stretch of Bridge Creek. Eighty percent of these dams were blown out in less than two years. Of those, 69% were gone in less than a year. Currently, there are just three small, active dams in the area, all of them built in Autumn, 2006. The different colored dots refer to different years that the dams were built (Data provided by Rick Demmer, BLM).

Figure 5. A two year-old beaver dam blown out by high flows in the spring of 2006.

locations, especially where the incised stream has widened substantially (> 50 m). In these locations, it appears that the beaver ponds have remained stable enough for their offspring to be raised, and that these young beaver eventually disperse to other, less habitable reaches in Bridge Creek, where they persist for 1-2 years and then disappear when the spring floods blow out their weak dams (Figure 5). The result is that the beaver population has not greatly expanded in the past 20 years, being restricted to just a few stable colonies in one reach, and their full potential benefits to the stream system have not been realized.

Our restoration approach then is to provide beaver with the structure and material that they need to construct and maintain dams in Bridge Creek that will have a longer lifespan. Field observations and calculations indicate that along many reaches of Bridge Creek, there is enough sediment moving through the system for them to back fill completely in less than 10 years (Pollock et al., in review). Thus if we provide beaver with the tools they need to construct and maintain relatively stable dams, the system should be able to restore itself without further intervention.

Expected habitat changes and impacts to O. mykiss

The restoration actions should restore hydrologic processes that will increase baseflows, lower summer temperatures, decrease sediment loads and create greater habitat complexity such as more off-channel habitat, more riparian vegetation, and more frequent and deeper pools. These increases in habitat quality and quantity will increase the carrying capacity of the system for juvenile *O. mykiss*. To illustrate this, over the course of a year we compared steelhead densities in Bridge Creek beaver ponds with nearby habitat where ponds were absent. Beaver pond had higher densities of juvenile *O. mykiss* in all seasons, particularly in spring and winter (Figure 6).

Greater habitat complexity also provides juvenile steelhead refuge from predation, interference competition, and high velocity current. The expected

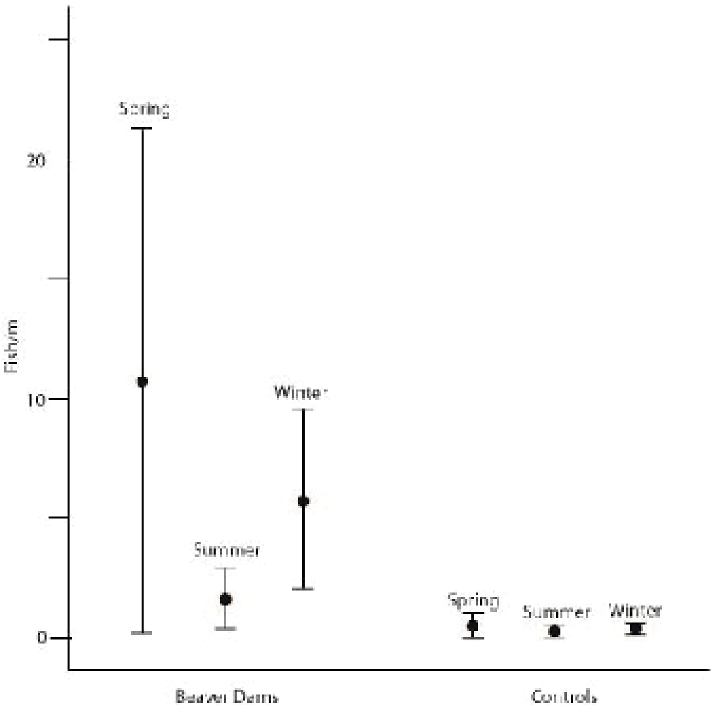

Figure 6. Regardless of the season, the pools behind beaver dams consistently have more fish than adjacent similar reaches, though in the summer, the differences are much less than in winter and spring (n=3 for beaver dams and controls for each season). Data are from Bridge Creek.

decrease in temperature should also reduce predation by warm water species such as the exotic smallmouth bass found in this system either through thermal displacement or lowering energetic demand.

Decreased temperatures will also provide a thermal environment closer to the energetic optima of *O. mykiss*, resulting in an increase in growth rates. In addition, allocthonous inputs will increase with an increase in floodplain connectivity and riparian vegetation, boosting primary and secondary production, and increasing growth rates of fishes. Decreases in energetic expenditures (e.g. temperature and refuge, increases in energetic inputs (e.g. production), and decreases in mortality (e.g. predation) are expected to increase survival and production. Decreased sedimentation will lead to a decrease in gravel and cobble embeddeness, providing increases in suitable spawning gravels, and habitat complexity for periphyton, benthic invertebrates, and parr. Egg survival is also expected to increase as entombment of eggs by sediments is decreased.

Comparison of observed parr densities in Bridge Creek with densities in nearby healthy watersheds suggests that the restored reaches will potentially increase steelhead rearing capacity approximately 30 fold. Using available parr and smolt survival estimates for the John Day River, we calculate that every 4 km of stream we restore will result in an additional 79 steelhead adult spawners returning to Bridge Creek. The existing population is poorly documented because spawner surveys are infrequent, but based on the limited spawner survey data from ODFW, we estimate that 4 km of fully restored stream would roughly double the current Bridge Creek population.

Experimental Design and Monitoring Approach

We will make comparisons between treatment and controls, before and after the implementation of the restoration actions as a means to increase the power to detect changes in the physical habitat and steelhead responses. These before-after-control-impact (BACI) designs have been employed in areas where replication is low or not possible to best detect environmental impacts (Steward-Oaten and Bence 2001, Downes et al. 2002). We plan to implement BACI-like designs is a nested hierarchy to compare restored and unrestored areas at the watershed, subwatershed, and reach scales. At the largest scale, the Bridge Creek watershed will be compared to a similar nearby watershed, Murderer's Creek (Bouwes 2006). Within the Bridge Creek watershed, changes in the mainstem will be compared to two unmanipulated tributaries, Bear Creek and Gable Creek. At the highest level of resolution, comparisons will be made between control and manipulated reaches of the mainstem of Bridge Creek. The hierarchical design will help identify the scale of influence of the restoration actions (which may differ between physical habitat and steelhead responses) and the appropriate scale at which restoration efforts of this type should be monitored (Underwood 1994). Pre-project monitoring has been implemented in Bridge Creek, Gable Creek, and Bear Creek since 2005, and we plan to collect pre-project data in 2007. Intensive monitoring has been occurring in Murderers Creek since 2004. Post-project monitoring may last approximately 10 yrs; however, if large changes in responses occur earlier than this, then further intensive monitoring will not be required.

Restoration Plan

Our restoration plan is to accelerate the natural process of aggradation that occurs in incised streams. Our strategy is to utilize beaver and provide them with materials to create stable dams that trap sediment and aggrade the stream sufficient to reconnect it to its former floodplain. Analysis of Bridge Creek indicates that it has a high sediment load and that were sediment retaining structures in place, the majority of reaches would be reconnected to their floodplain within several decades, many of them within less than a decade (Pollock et al., in review).

This contrasts with a common (and expensive) approach for "restoration" of incised streams, which is to excavate material to create a narrow inset floodplain and a new sinuous channel within this floodplain (Rosgen, 1996). This provides immediate partial function, but then requires centuries for reconnection of the stream to its historic floodplain. This approach also requires the extensive use of heavy machinery and involves a tremendous amount of work and expense. It is a highly engineered approach. Such restoration projects can cost hundreds of thousands of dollars per stream kilometer. Notably, this approach also delays raising the water table within the stream-adjacent alluvium. This is an especially significant concern in semi-arid areas such as the Bridge Creek watershed, because many such streams have incised to bedrock and therefore the water table is at or near the bedrock and there is little opportunity for alluvial water storage. As a result, many incised streams cease flowing or have substantially reduced flows in the summer because there is no baseflow provided by the alluvial aquifer. In contrast, a number of examples exist where the construction of beaver dams or small check dams allowed streams to aggrade and water tables to rise, and formerly seasonal streams developed perennial flow (Stabler, 1985; DeBano and Heede, 1987; Ponce and Lindquist, 1990; Pollock et al., 2003). Thus restoration strategies involving the construction of an inset floodplain can actually delay recovery of an important hydrologic function and cause long-term damage to the system as a whole.

Beaver dam enhancement structures

Our restoration strategy is to utilize beaver and provide them with materials to create stable dams that can create pools, trap sediment to aggrade the stream, and increase riparian areas upstream of the dams. Essentially, we are creating stable beaver colonies that will do the majority of the work required to connect the stream to the former floodplain. Using LiDAR (Light Detection and Ranging) data and field measurements, we have identified and prioritized reaches along the mainstem of Bridge Creek where geomorphic conditions are suitable for placement of beaver dam enhancement structures and the creation of a stable colony. Criteria selection included stream gradient, incision depth, floodplain width and presence of upstream sediment supplies.

To succeed with this restoration approach we need four components: 1) pools that can provide immediate habitat for beaver, 2) anchoring structures that can be used by the beaver to create stable dams, 3) dam building materials and 4) beavers. Finally, we will also plant riparian woody species, primarily cottonwood, to help ensure a long-term food supply for beaver.

Pools.— Pools are created by using cobble, juniper logs and posts to back up water sufficient to create a pool > 0.5 m deep. They are essential to the success of the project because they provide an immediate haven for beaver so they have protection from predators (primarily coyote) while they become established in their new location. Experience has shown that predation mortality of both transplanted and dispersing 2 year-old beaver can be very high when they are placed in streams without adequate pool habitat. We are working with ODFW to ensure that these present no fish passage issues for adult or juvenile steelhead.

Stabilization structures.— Because most of the beaver dams currently built on Bridge Creek have a very short life span, we will install fence posts that the beavers can utilize to anchor their dams. For these structures, a series of posts or poles will be installed into the bed substrate perpendicular to the flow of the stream (Figure 8), preferably near natural constrictions with low-gradient upstream reaches.

On existing inset floodplains, juniper logs will also be placed next to the poles and pinned in place with the poles to provide additional structure.

These posts provide key structural support that can be used by beaver to build durable dams able to withstand high flow events. These dams should last until the pool behind the dam can backfill with sediment and be colonized by woody riparian vegetation, a process that typically takes 5-10 years in Bridge Creek. A series of posts lines will be placed in close proximity to mimic typical frequencies and heights of beaver dams, and will be built around the nucleus of a starter pool. A common layout for a well established beaver colony is a primary dam 1-1.5 m high with a series of 3-6 intermediate-sized (0.5-1 m) dams upstream or downstream of the primary dam, and spaced 30-100 m apart, depending on stream gradient, such that a series of connected pools is created that provide a safe upstream-downstream travel corridor for beaver.

As an example, on Bridge Creek in 2005, there were four relatively stable colonies, each impounding about 250 m of total stream length. Two had constructed six dams, another had three dams and another seven dams. All but one of the colonies with six dams had a single secondary structure downstream of the primary dam. The oldest dam in three of the colonies was five years, and the oldest dam was six years in the other. As a sidenote, all the oldest dams had filled with sediment, to the extent that the only remaining pool habitat was immediately upstream of the dam and in the passageways or "canals" that the beaver maintained through the sediment and emergent vegetation. All but one of the 22 dams were blown out in the winter and spring floods of 2006, and only two of the colonies were starting to rebuild by the summer of 2006.

Building material.— At each site where pools are created and post-pile fence lines are constructed we will also provide an ample supply of 2-10" diameter cottonwood, willow (and if possible aspen) boles and branches for beaver during the dam-building season (late summer-early fall) to ensure they have adequate food and dam-building material. The large diameter wood is especially important so that the beaver can build strong dams capable of withstanding high flows during the spring. The material will be placed either in the starter pool or adjacent to the pool on the shore such that the beaver can easily access the food without making themselves vulnerable to predators. Past experience has shown that for a transplanted family of beaver, a flatbed pick-up load of wood usually provides an adequate supply of food and dam-building materials for a year (Figure 9).

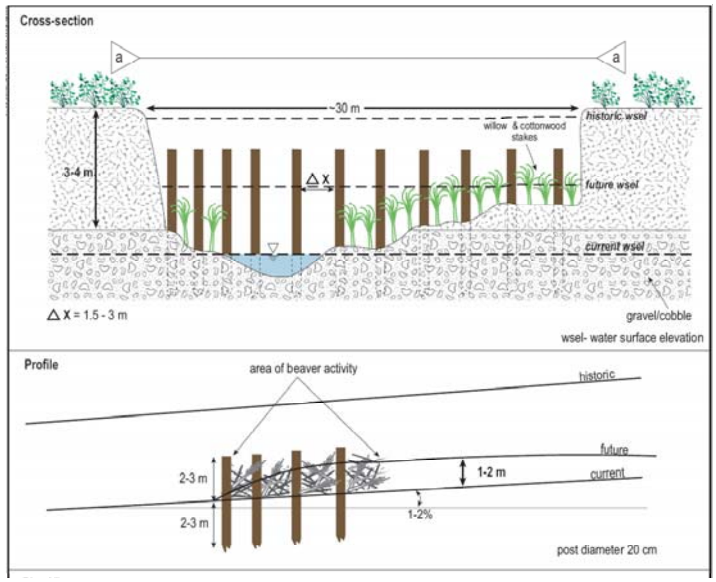

Figure 8. Schematic of a post-pile fence design to facilitate beaver dam construction-another "soft engineering" approach for causing aggradation of an incised stream bed.

Beaver.— At some of the sites with a starter pool and a series of anchoring structures, we will transplant "nuisance" beave when obtainable preferably using entire families when possible. Sub-adult beaver (usually second year) are less experienced that adult pairs in building dams and their mortality rate tends to be higher after transplanting. Paired adults, or adults with yearlings tend to get focused on dam-building much more quickly after being transplanted and as a result have higher survival rates. Beaver transplanting will occur in the late-summer, at the start of the beaver dam-building season, when food will be supplied and when they are less likely to wander due to the immediate need to build safe habitat before the coming of winter (Figure 10).

Riparian Tree Planting.— Finally, we will plant and fence cottonwood near our study sites. This isn't absolutely essential to the success of the project, as natural regeneration of willows and to a limited extent, cottonwood, will occur where hydrologic conditions are suitable. However, by planting extensively and fencing, we help to ensure a long-term supply of highly-edible wood for the beaver. We will plant cottonwood stakes in the early spring, using data from our water level monitoring wells to ensure they are planted deep enough to access water year round. We will also protect the trees with wire cages and exclosures so they are protected against both beaver and elk, similar to what the BLM has done in some reaches along Bridge Creek.

Site Locations

We have analyzed the lower 31 km of Bridge Creek using LiDAR, digital photographs, additional GIS data and field surveys to identify and prioritize each reach in terms of its potential to support a stable beaver colony using our restoration approach (Figure 11 and Table 1). Our primary consideration was the geomorphic characteristics of the reach, and in particular, whether the beaver dams were likely to raise the water table high enough to reconnect the stream to the former floodplain in a reasonable time frame. This was an important consideration because reconnecting the stream to its floodplain substantially increases both the quantity and quality of instream and riparian habitat. Some reaches had little in the way of accessible floodplain because they were in narrow, confined valleys, or more commonly, constrained by coalescing alluvial fans from side valley drainages. In a few cases some reaches had wide potentially accessible floodplains, but were not considered a high priority because the landowner was not rated as cooperative at the time of the analyses.

Figure 10. Releasing beaver into their new home. Once trapped, beaver become relatively docile, and transport well provided they have food and can thermoregulate. Mortality using live snare traps or Hancock traps is low, but sometimes it is difficult to capture an entire family (photograph courtesy of Kevin Spence, WDGF).

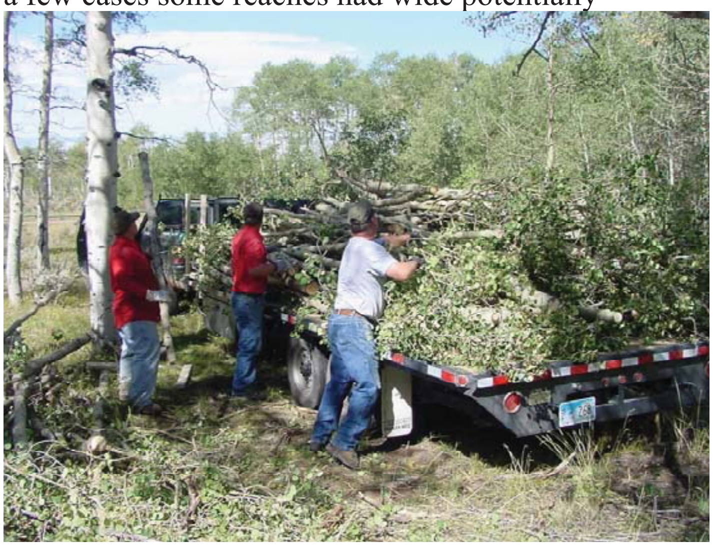

Figure 9. A trailer load of wood such as this will provide a colony of beaver enough food for a year (photograph courtesy of Kevin Spence, Wyoming Department of Game and Fish).

Phasing of restoration activities

Because we want to maximize the potential for detecting a population-level effect on the steelhead, over the long–term we intend to restore as many of the reaches of the lower 31 km of Bridge Creek where there is a reasonable potential to reconnect the stream to its former floodplain (about 20 km). However, this will be done in phases so that we can adapt our techniques as conditions warrant. Initially (2007), we would like to restore one or two reaches (< 0.5 km) as a pilot study to demonstrate and refine our restoration techniques. If the initial pilot study is unsuccessful, we would spend the following year (2008) continuing to refine our techniques. However, if the pilot studies demonstrates positive results, the following year (2008), we would like to restore an additional 4 km of stream or create approximately 8 additional beaver colonies in the high priority areas. Each year for the next 4 years we would then restore another 3-4 km of stream until we have reached our target of 20 km.

Table 1. Reach characteristics for the lower 32 km of Bridge Creek. The term "potential recovery" refers to the width of the accessible floodplain at a certain level of aggradation relative to the width of the natural meander belt (width of the area that the stream would be expected to meander within under natural conditions, given the stream size and valley gradient). Potential Recovery is an important metric used to prioritize restoration efforts.

Reach	General Location	Landowner	Stream Length (m)	Stream Slope (%)	Valley Length (m)	Sinu osity	Valley Slope (%)	Potential Recovery at 2 m aggradation	Potential Recovery at 2.5 m aggradation	Potential Recovery at 3 m aggradation
01	Above Owens	Pvt	167	2.6	163	1.0	2.6	33%	44%	50%
02	Above Owens	Pvt	231	1.9	208	1.1	2.1	55%	58%	61%
03	Above Owens	BLM/Pvt	188	2.7	177	1.1	3.0	36%	44%	49%
04	Above Owens	BLM	306	2.3	280	1.1	2.5	19%	24%	33%
05	Above Owens	BLM	664	2.1	604	1.1	2.3	32%	47%	60%
06	Above Owens	BLM	131	2.0	127	1.0	2.0	15%	18%	21%
07	Above Owens	BLM	139	1.5	137	1.0	1.6	17%	26%	49%
08	Owens Ranch	BLM	214	1.5	203	1.0	1.6	20%	26%	32%
09	Owens Ranch	BLM	296	1.6	205	1.4	2.3	54%	61%	69%
10	Owens Ranch	BLM	551	1.8	431	1.3	2.3	55%	68%	78%
11	Owens Ranch-W1	BLM	903	1.7	772	1.2	2.0	54%	82%	103%
12	Owens Ranch	BLM	294	1.7	241	1.2	2.1	40%	46%	52%
13	Owens Ranch	BLM	455	1.7	412	1.1	1.9	47%	62%	77%
14	Owens Ranch	BLM	270	1.3	233	1.2	1.5	55%	64%	73%
15	Owens Ranch-W2	BLM	549	1.7	433	1.3	2.1	86%	108%	129%
16	Along Hwy 26	BLM	315	1.7	298	1.1	1.8	24%	31%	39%
17	Along Hwy 26	BLM	193	1.5	185	1.0	1.6	38%	67%	71%
18	Along Hwy 26	BLM	202	1.5	197	1.0	1.5	18%	20%	22%
19	Along Hwy 26	BLM	108	0.9	107	1.0	0.9	41%	44%	46%
20	Along Hwy 26	BLM	194	1.2	172	1.1	1.4	61%	70%	79%
21	Along Hwy 26	BLM	161	1.9	162	1.0	1.9	24%	30%	37%
22	Along Hwy 26	BLM/Pvt	296	1.8	279	1.0	1.9	20%	25%	28%
23	Junction Ranch	Pvt	176	1.6	162	1.1	1.7	40%	194%	225%
24	Junction Ranch	Pvt	409	1.4	340	1.2	1.7	64%	72%	83%
25	Junction Ranch	Pvt	320	0.8	280	1.1	0.9	84%	99%	113%
26	Above Meyers	BLM/Pvt	1147	1.1	846	1.4	1.5	49%	53%	56%
27	Above Meyers	BLM	463	1.1	331	1.4	1.5	29%	37%	51%
28	Above Meyers	BLM	358	1.0	301	1.2	1.1	50%	59%	62%
29	Above Meyers	BLM	197	1.1	153	1.3	1.4	35%	38%	40%
30	Below Meyers	BLM	356	1.2	315	1.1	1.4	21%	25%	29%
31	Below Meyers	BLM	261	0.8	251	1.0	0.9	24%	30%	43%
32	Below Meyers	BLM	624	1.1	559	1.1	1.3	24%	29%	35%
33	Below Meyers	BLM	500	1.0	430	1.2	1.2	37%	43%	47%
34	Below Meyers	BLM	492	1.2	387	1.3	1.5	23%	35%	63%
35	Below Meyers	BLM	1084	1.3	932	1.2	1.5	19%	26%	33%
36	Below Meyers	BLM	569	1.2	541	1.1	1.2	14%	16%	20%
37	U Monument	BLM	142	1.0	119	1.2	1.2	21%	23%	30%
38	U Monument	BLM	190	1.1	144	1.3	1.5	27%	28%	29%
39	U Monument	BLM	65	1.0	64	1.0	1.0	11%	32%	44%
40	U Monument	NPS/BLM	266	0.8	184	1.4	1.2	16%	18%	20%
41	U Monument	NPS/BLM	138	0.9	83	1.7	1.5	17%	23%	32%
42	U Monument	NPS/BLM	329	1.0	217	1.5	1.5	20%	22%	24%
43	U Monument	NPS/BLM	116	0.9	111	1.1	1.0	16%	18%	21%
44	U Monument	NPS/BLM	194	0.9	106	1.8	1.6	21%	23%	25%
45	U Monument	NPS/BLM	164	0.3	150	1.1	0.3	22%	24%	27%
46	U Monument	NPS/BLM	121	0.7	105	1.2	0.7	70%	74%	77%
47	U Monument	NPS/BLM	138	1.4	74	1.8	2.4	44%	45%	46%
48	U Monument	NPS/BLM	456	0.8	351	1.3	1.0	28%	30%	33%
49	L Monument	NPS/BLM/Pvt	695	0.8	494	1.4	1.1	64%	69%	74%

Reach	General Location	Landowner	Stream Length (m)	Stream Slope (%)	Valley Length (m)	Sinu osity	Valley Slope (%)	Potential Recovery at 2 m aggradation	Potential Recovery at 2.5 m aggradation	Potential Recovery at 3 m aggradation
50	L Monument-W	NPS/BLM	259	0.5	150	1.7	0.9	92%	99%	106%
51	L Monument	NPS/BLM/Pvt	237	1.1	188	1.3	1.4	99%	118%	150%
52	L Monument	NPS/Pvt	236	0.9	189	1.2	1.1	39%	81%	100%
53	L Monument	NPS/Pvt	251	0.6	206	1.2	0.8	42%	49%	53%
54	L Monument	NPS/Pvt	406	0.6	289	1.4	0.9	25%	31%	117%
55	L Monument	NPS/Pvt	126	1.2	82	1.5	1.8	31%	33%	106%
56	L Monument	NPS/Pvt	105	1.3	79	1.3	1.7	25%	49%	68%
57	Taylor Ranch	NPS/Pvt	1080	1.0	928	1.2	1.2	18%	20%	23%
58	Taylor Ranch	Pvt	491	0.8	388	1.3	1.0	119%	168%	202%
59	Taylor Ranch	Pvt/NPS	1006	0.9	794	1.3	1.1	43%	56%	79%
60	Taylor Ranch	Pvt	512	1.0	470	1.1	1.0	16%	19%	23%
61	Taylor Ranch	Pvt	253	0.6	175	1.4	0.8	39%	43%	49%
62	Taylor Ranch	Pvt	430	0.7	322	1.4	1.0	58%	68%	77%
63	Taylor Ranch	Pvt	516	0.7	468	1.1	0.8	61%	89%	150%
64	Taylor Ranch	Pvt	380	0.7	268	1.4	1.0	70%	85%	120%
65	Taylor Ranch	Pvt/BLM	309	0.7	217	1.4	1.0	79%	93%	109%
66	Connely Ranch	BLM	461	0.9	326	1.4	1.2	90%	105%	111%
67	Connely Ranch	BLM	291	1.1	271	1.1	1.2	48%	54%	95%
68	Connely Ranch	BLM	533	0.8	364	1.5	1.2	39%	41%	45%
69	Connely Ranch	BLM	299	1.0	283	1.1	1.1	86%	91%	95%
70	Connely Ranch	BLM	393	0.7	378	1.0	0.7	22%	24%	27%
71	Junction Corral	BLM	451	0.9	353	1.3	1.1	113%	122%	133%
72	Junction Corral	BLM	283	1.1	249	1.1	1.2	67%	81%	89%
73	Junction Corral	BLM	935	1.1	649	1.4	1.5	28%	35%	43%
74	Sunflower Ranch	BLM	442	0.9	387	1.1	1.1	28%	39%	90%
75	Sunflower Ranch	BLM	378	1.0	293	1.3	1.3	74%	90%	107%
76	Below Sunflower	BLM	325	1.2	274	1.2	1.4	28%	35%	38%
77	Below Sunflower	BLM	239	1.5	228	1.0	1.5	20%	22%	25%
78	Below Sunflower	BLM	1067	1.4	1013	1.1	1.5	19%	24%	31%
79	Below Sunflower	BLM	388	1.2	385	1.0	1.2	19%	28%	58%
80	Below Sunflower	BLM	333	1.3	313	1.1	1.4	29%	45%	57%
81	Near Gaging Stn	BLM	588	1.2	555	1.1	1.3	22%	35%	47%
82	Near Gaging Stn	Pvt/BLM	398	0.9	380	1.0	1.0	22%	39%	54%
83	Near Gaging Stn	BLM	439	1.2	401	1.1	1.3	52%	58%	62%
84	The Mouth	Pvt	288	1.2	282	1.0	1.3	100%	135%	165%

Experimental Design

Nested Hierarchical Design

We will employ a nested hierarchical design to compare steelhead use and physical habitat conditions of restored and unrestored areas at the watershed, subwatershed, and reach scales. This experimental design will maximize our ability to detect responses as a function of the restoration action. At the watershed scale, Bridge Creek will be compared to nearby Murderer's Creek, where ongoing monitoring of steelhead populations and physical habitat conditions is already occurring. Within the Bridge Creek watershed, comparisons will be made between two tributaries (Bear Creek and Gable Creek) and the mainstem. Within the mainstem of Bridge Creek comparisons will be made between control and manipulated reaches, separated by enough distance to minimize movement between reaches by parr. Pre-project data has been collected in Bridge Creek, Gable Creek, and Bear Creek since 2005, and we plan to gather another year of pre-project data in 2007. Post-project monitoring is expected to last approximately 10 yrs; however, large changes in responses may occur earlier than this and may obviate the need for further intensive monitoring.

The experimental design for the evaluation of Bridge Creek restoration projects will differ slightly depending on the response variable and spatial scale. The only replicates in treatments are at the

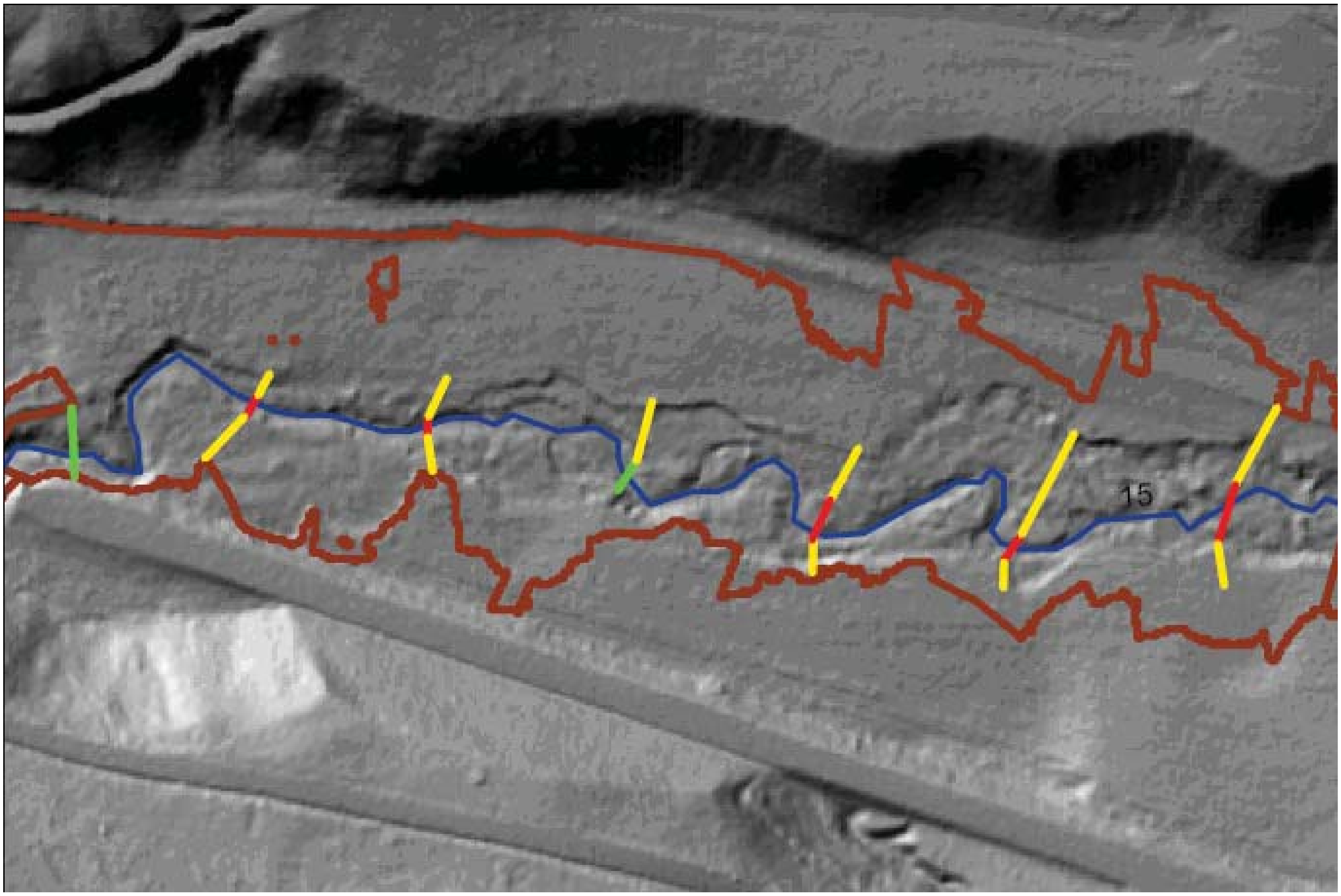

Figure 11. A LiDAR image of reach 15 (about 430 m) on the mainstem of Bridge Creek showing where the starter pools and post pile lines needed to establish stable beaver colonies could be constructed. Legend: Green lines = starter pools, red and yellow lines = post-pile lines, with the red lines representing the area in the existing channel. The outer polygon is the approximate boundaries of riparian area that will be created if 1.5 m high beaver dams are constructed (approximately equal to the 2 year floodplain).

reach scale. If responses are independent between reaches, than reach scale comparison will likely be the most powerful because 1) there a replicates of both treatment and controls and 2) shared characteristics (e.g. climate) between treatment and control are likely most similar at this scale. As mentioned above, approximately 4 km reaches per year will be manipulated due to logistical constraints (as opposed to all 25 km manipulated in a single year). Thus at the reach scale, we will implement the dams in a staircase design with treated reaches starting on different years. In a staircase design, multiple treatment and control sites are sampled; however, treatments are staggered through time to determine whether responses can consistently be produced by the manipulation regardless of the starting conditions (Walters and Collie 1986). For example, the frequency of high flow events, which will likely differ from year-to-year, may determine initial success of dam construction. Responses in on-site habitat characteristics such as changes in riparian vegetation, aggradation rates, and water table levels are perhaps best viewed at the reach scale and thus appropriate comparisons can be made with the staircase design. We will have PIT tag detectors and weirs dividing control and treatment reaches at a minimum of three locations. If fish movement of juvenile steelhead is minimal between these reaches then reach level comparisons using a staircase design is also appropriate for responses such as growth rates and seasonal survival rates.

Several other responses will likely have to be compared at a larger spatial scale due to a lack of independence between reaches. Changes in some habitat conditions, such as temperature and mean summer discharge, may propagate downstream to other control and treatment reaches in which case reaches would not be independent and comparisons of these response should be made at a larger scale (e.g. between tributaries-Gable and Bear Creeks- and mainstem of Bridge Creek). Likewise, juvenile steelhead movement between reaches and perhaps between tributaries is possible, in which case larger scale comparisons will have to be made. At the scale of tributaries and watersheds (i.e. Murderers and Bridge Creeks) we will compare a time series of relevant habitat and fish of responses prior to the manipulation to a time series after the manipulation. Intervention Analysis (IA) have been used for these types of comparisons (Box and Tiao 1975, Steward-Oaten 1986, Carpenter et al. 1989). A Before-After-Control-Impact (BACI) approach is an IA with non-manipulated sites used as a covariate, thus the "controls" are used to reduce variation but are not used to measure it as do true experimental controls (Steward-Oaten and Bence 2001). The difference between the manipulated and the control responses are calculated for every sample event and these are averaged for the pre- and post-treatment periods, or Ď(PRE) and Ď(POST), respectively. The test statistic is |Ď(PRE)- Ď(POST) | and is compared to a theoretical distribution (e.g. BACI; Steward-Oaten et al. 1986) or a distribution of random permutations of the observed sequence of treatment and control differences (e.g. a Randomized Intervention Analysis; Carpenter et al. 1989). The latter of these is not constrained by the assumptions of parametric statistics (for a comparison of BACI and RIA see Cloutman and Jackson 2003). By evaluating the difference in treatment and control, shared characteristics (e.g. climatic conditions, mainstem Columbia River, estuary and ocean conditions, geology and vegetation types, changes in monitoring personnel) tend to cancel out. Thus, the benefit of a control as a covariate, capturing multiple parameters, becomes more apparent. If treatment and control watersheds differ substantially in a characteristic as to swamp the effect of the treatment then these characteristics can be used as covariates to aid in partitioning these sources of variability from the differences caused by the treatment. Techniques are available to select useful covariates from a list of potential covariates measured throughout the study period (Milliken and Johnson 2001, Kershner et al. 2004). Further refinement to statistical models can account for temporal autocorrelations, cyclic effects, and gradient effects (Draper 1984, Steward-Oaten and Bence 2001).

We are using the hierarchical design approach for several reasons. First, by including multiple controls at different scales, we are protecting against the possibility that something could go wrong with the one control approach, such as a large scale disturbance. Second, we are uncertain to the degree restoration may impact downstream reaches. Although a comparison of multiple reaches within a single watershed may be more powerful because of higher replicability and the ability to accurately describe a reach versus a watershed or subwatershed, these sites may not be independent from each other, depending on the degree of movement by *O. mykiss*, and the degree to which physical impacts from treated reaches propagate into the next study reach. Underwood (1994) suggests a nested hierarchical approach when the scale of impact is unclear. Third, we are also evaluating the degree of variability and statistical power associated with each scale (Underwood 1994). The latter two points will provide insight into the scale at which future restoration actions should be monitored. Fourth, this hierarchical design will also lend itself to the testing and development of causal relationships pursued in monitoring and research programs currently being implemented in the John Day RME pilot program. These relationships include fish-habitat relationships, relationships between instream characteristics, and relationships between landscapes, habitat, and fish, and thus require multi-scale information. The multi-scale approach will be robust and flexible enough to account for range of responses we are likely to observe.

Murderer's Creek as a control watershed

As mentioned, we will be using another watershed as a control watershed to compared to Bridge Creek. We have chosen to use Murderers Creek, a tributary to the South Fork John Day as the control watershed for several reasons. First, an intensive research program is currently being implemented in the South Fork John Day by Oregon State University (Bouwes 2005). Approximately, 12,000 *O. mykiss* juveniles have been PIT-tagged in the tributaries of Black Canyon and Murderers Creek starting in 2004. Thus, information has been obtained regarding juvenile seasonal survival, movement, and abundance patterns (Tattam 2007). In addition, extensive habitat surveys and LiDAR have been conducted throughout this study area. The researchers involved in this study have been collecting the pre-project monitoring data for Bridge Creek as well. Thus, the pre-project information collected in the South Fork IMW is not only paid for but is also compatible to Bridge Creek information that has been and is planned to be collected. This cost share between research projects also highlights the importance of a network of IMWs. Second, Murderers Creek is within relatively close proximity to Bridge Creek and likely shares similar climatic conditions, mainstem Columbia River, estuary and ocean conditions. Murderers Creek is a similar size to Bridge Creek, with both creeks situated in watersheds with a similar history of land use activities, primarily ranching. Third, Murderers Creek is owned and managed by the state of Oregon and thus access to further studies is ensured. Because the geology of Murderers Creek basin is primarily basalt, it is not as incised as Bridge Creek. Also, while all of the riparian area of the mainstem of Murderers Creek has been protected from grazing for several decades, there are still about 15% of Bridge Creek mainstem riparian areas that are not protected. Although these differences prevent Murderer's Creek from being the perfect control, this watershed serves the purpose to act as a set of covariates in a BACI design to factor out noise in the difference between pre- and post-manipulations of Bridge Creek.

Monitoring Design

Below we provide the details of the monitoring we plan to execute within the study area. A summary of this information is provided in Appendix 1.

Steelhead monitoring

Described below is the monitoring program we will follow to estimate before and after treatment fish responses in the control and treatment areas across multiple scales for our response variables. We will monitor several life-stages throughout the study areas, including parr (age 0 to pre-smolt which range in age from 1-4 yrs old), smolts, and adults.

To evaluate whether fish are responding to changes in habitat as expected we will monitor several response variables: 1) Spatial distribution as measured by changes in relative density (juvenile *O. mykiss*, and other fish species); (2) population abundance

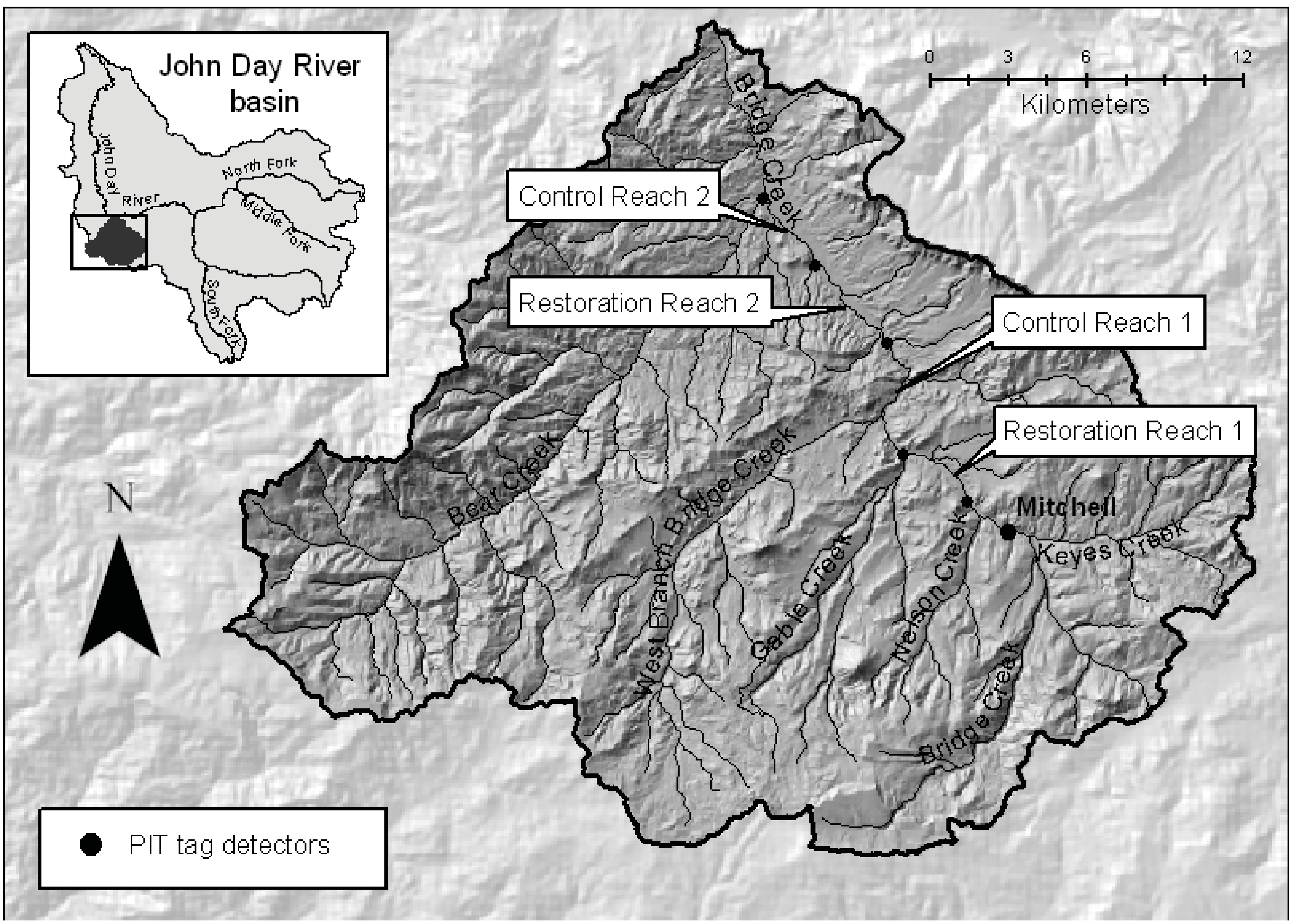

Figure 12. Map of Bridge Creek showing approximate locations of proposed restoration and control reaches and proposed PIT tag detectors and smolt traps. Smolt and adult traps will measure watershed and subwatershed abundances, and PIT tag detectors will be used to describe movement between reaches and survival information.

(*O. mykiss* parr, smolts, and other fish species); (3) seasonal survival (juvenile *O. mykiss* and smallmouth bass) (4) parr-to-smolt survival (*O. mykiss*); (5) smolt-to-adult return (SAR- *O. mykiss*); and (6) recruiting adults (R/S- *O. mykiss*); (7) smolts per redd or per spawner (*O. mykiss*); (8) egg-to-parr (*O. mykiss*); (9) egg-to-smolt survival (*O. mykiss*); (10) migratory timing, size, and growth rates (*O. mykiss* parr and smolts).

This study takes advantage of recent technological advances in extended length PIT tag detectors to obtain > 95% detection efficiency of tagged fish that pass through reaches with antennas. PIT tag detectors will be placed in treated and untreated reaches within Bridge Creek, and near the mouths of Bridge, Bear Creek, Gable Creek and Murderer's Creek (Figure 12). PIT tag antennas will provide information on movement (or degree of independence) between reaches, and other metrics described below. In addition, the movement information will describe the importance of the potomandromous (seasonal movement between mainstem and tributaries) life history strategy as observed in the South Fork of the John Day IMW. This strategy is thought to occur because of an interaction between behavioral thermoregulation and density dependent interactions, where a percentage of the population uses cooler tributaries in the summer, migrates out in the fall to rear in the warmer mainstem John Day, and potentially returns to the tributaries as mainstem temperatures become too warm in the summer (Tattam 2007). The relative use of tributaries and mainstem for thermoregulation is a life-history strategy for steelhead that requires further investigation (CBMRC 2005, Tim Unterwegner and Jim Ruzycki of ODFW, personal communication).

Parr abundance and distribution will be estimated through a combination of snorkeling surveys, snorkel-herding and electro-herding (electroshocker set to a low setting that is irritating but will not stun) into bag seines. Snorkel- and electro-herding will be used to capture fish to PIT tag, estimate abundance through mark-recapture population estimates, as well as to calibrate snorkel surveys that are used by ODFW (Figure 14).

Figure 14. A typical juvenile *O. mykiss* from Bridge Creek, captured and PIT tagged in Autumn of 2005.

These methods have been calibrated in the South Fork John Day IMW (Bouwes 2005). A census using snorkel/herd-seining surveys may be conducted over the entire study area. In some areas these surveys will not be logistically feasible, such as in beaver ponds where disturbance of sediments will preclude visual estimates, or in shallow waters that cannot be reasonably observed. In such instances, 3-pass electroshocking or mark-recapture Peterson abundance estimates will be conducted for each habitat unit. These surveys will also be used to collect juvenile *O. mykiss* to be PIT tagged. Further sampling may be required to capture more fish to increase the sample size of PIT tagged fish. Surveys will be conducted in Bridge Creek and tributaries as well as in Murderers Creek at the beginning of June and the end of September, and in early January, providing information on summer, fall, and winter/spring habitat use. Habitat surveys will be conducted at these sites as well. Changes in fish density will be used to assess changes in habitat quality, with the assumption that fish select for higher quality habitat as a means to increase fitness. This assumption will be verified by comparing these responses to surrogates of fitness, mainly growth and survival rates. These surveys can be used to address reach scale comparisons or combined to assess larger scale comparisons.

Mark-recaptured models based on PIT tag information will be used to estimate seasonal parr survival, parr-to-smolt survival. Juvenile *O. mykiss* will be marked with PIT tag during abundance and distribution surveys and will be recaptured in subsequent surveys and detected at PIT tag antennas in the study watersheds. Cormack-Jolly-Seber (CJS) models have typically been used to estimate survival over discrete sampling events, which in this study would be over the 3 time periods described in the abundance and distribution surveys. However, PIT antennas provide continuous information that can be incorporated into more complex mark-capture models, mainly the Barker model. In this model, detections between sample periods will provide additional information which can be used to estimate immigration and emigration parameters. Therefore, we plan to conduct a robust design Barker approach for tagging juveniles. Fish will be sampled over a minimum of 3 consecutive days per reach for each sample event in the abundance and distribution survey. The consecutive sampling events will provide higher precision estimates of capture probabilities, resulting in more precise survival estimates. Multiple mark-recapture type models with different sets of covariates such as; time at release, size, number of times recaptured, and habitat features influence on survival rates can be compared in an information theoretic framework (White et al. 1999). In addition to seasonal parr survival estimates, smolt reach survival in the mainstem John Day and Columbia River, and smolt-to-adult survival between reaches, subwatersheds and watersheds will also be made using PIT tagged fish. PIT tag antennas in the study watersheds, on the mainstem John Day (construction of PIT tag antenna on the mainstem of the John Day River near the confluence with the Columbia is currently being proposed), and John Day and Bonneville dams on the Columbia River will be used to make these estimates.

Power Analyses

Using the program MARK (White and Burnham 1999), we simulated Cormack-Jolly-Seber apparent survival and capture probabilities based on mark-recapture data from Murderers Creek (control watershed) to estimate sample sizes required to detect hypothetical changes in survival as a result of habitat restoration projects. We assumed a similar sampling schedule, which included summer, fall, and winter sampling, and considered three levels of effort, including 100 releases, 200 releases, and 400 releases per sampling period, and ran 1000 simulations for each scenario. We assumed a 50% increase in capture probabilities as a result of increased effort (such as the use of instream PIT tag detectors and robust sampling, which includes 3 successive sampling dates) and estimated the power to detect 50% increases in survival. Bradford et al. (2006) used a similar effect size to evaluated changes in habitat restoration on coho smolt and spawner production. Base inputs (apparent survival and capture probability) and increased inputs for simulations are shown in Table 2 below.

Table 2.

Season	Field estimates of survival	Survival increase of 50%	Field estimates of capture probability	50% Capture probability increase
Fa	0.303	0.455	0.306	0.459
Wi	0.266	0.399	0.323	0.485
Su	0.547	0.821	0.391	0.587

We estimated the number of samples required to achieve statistical power of 0.8 to detect this change in apparent survival (as a result of potential habitat restoration actions) using 80% confidence intervals, for fall, winter, and summer survival rates (e.g. Figure 13). Bradford et al. (2006) suggests this α and β values balance the costs associated with Type I and Type II errors. Based on these data we estimate we will need between 150 to 275 fish per sample period depending on season. Given that we have tagged approximately 200-300 fish to date per reach we believe we can accurately measure changes in survival estimates associated with the restoration actions.

This estimate assumes the distribution of survival based one year of information in Murderers Creek. Several years of study will increase our ability to detect changes greatly using a BACI (Bradford et al. 2006). We believe we can increase our statistical power by evaluating mark-recapture information using a Barker robust design approach, where preliminary information suggest much lower standard errors are associated with both survival and capture probabilities than a CJS approach (ISEMP 2006).

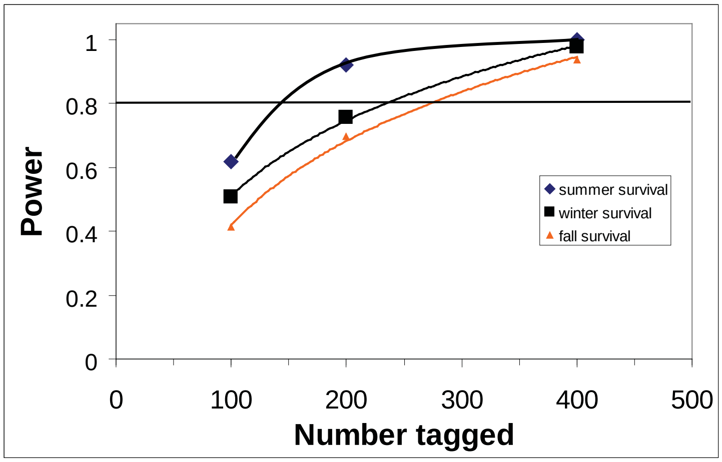

Figure 13. Estimated relationship between statistical power and number of fish tagged for Bridge Creek juvenile steelhead, by season.

A redd census and carcass survey will also be conducted in Bridge Creek, Bear Creek and Gable Creek. As adults begin to return from the first cohorts of PIT tagged juveniles, carcasses will also be scanned for PIT tags. In addition, fixed reaches and ten, 1 km long reaches selected in a random probabilistic design will be visited every two weeks throughout the season to quantify cumulative redd counts at each site, as is done for the ODFW steelhead surveys.

The number of smolts leaving and adults entering a watershed or subwatershed will be compared in this experiment as this gets to the most direct measure of interest, freshwater production or smolts per spawner. We will install removable two-way traps at the mouths of Bridge and Murderer's Creeks to capture outmigrating juveniles and incoming adults. The trap will be deployed daily to once a week and checked the next day. PIT tag antennas will be deployed above the traps to describe trap efficiency. All outmigrating juveniles captured in the traps will be scanned using a hand-held PIT tag detector or tagged if no tag is detected for further survival estimates (SARs). These traps will be operated during the migration seasons when possible. The traps will be used to capture adults migrating upstream to the spawning grounds. Adults will measured, aged, sexed and scanned for tags as well during the spawning season. This information will be used estimate recruits per spawner or overall life-cycle survival.

Egg-to-parr and egg-to-smolt survival will be estimated by dividing the number of parr estimated during the juvenile abundance and distribution, or the number of smolt captured in the traps, respectively, by the average number of eggs per female (determined through a literature review) multiplied by the number of females or redds. In addition, we will experiment with emergence traps to determine if this is a reasonable approach to estimating egg-to-emergent fry survival.

The size, timing, and age of out-migration smolts may provide information about changes to habitat quality. Length and weights of parr captured for tagging will be measured. Juveniles recaptured at the traps or in later juvenile surveys will also be measured to describe a change in biomass or growth. Growth rates will then be compared between reaches, subwatersheds, and watersheds throughout the study. Bioenergetics model can be used to further partition these changes in growth to changes in temperature and prey production. Growth rates and other information are a more proximate response to habitat quality than measures of survival allowing for a finer resolution evaluation of the impacts of these restoration actions on juvenile salmonids. Also, changes in the amount of time spent rearing in the different study areas will also provide us a more mechanistic understanding of impacts of restoration to this population.

All fisheries data collected over the life of this project will be georeferenced and stored and maintained in a geodatabase by NOAA Fisheries at the Northwest Fisheries Science Center.

Habitat monitoring

LiDAR and 3-band digital aerial photography remote sensing has already been conducted for Bridge Creek and Murderer's Creeks in 2005. We have analyzed these data to provide baseline data on stream and riparian habitat conditions within our study sites. These include: aerial extent of riparian vegetation, sorted by dominant vegetation type (e.g. willows, cottonwoods, emergent graminoids), stream geomorphology, including cross-section geometry, planform sinuosity, longitudinal gradient profile, and the location of beaver dams. Our goal is to repeat these remote sensing surveys over the study area every 5 yrs after completion of the project to measure changes in habitat quality and quantity and relate this to changes in juvenile *O. mykiss* productivity and biomass. Because LiDAR does not easily penetrate water, we will also measure and monument stream cross-sections at the restored and control sites so as to provide data on aggradation rates and volumes behind the structures relative to control sites, as well as providing detailed information on changes in the channel cross-section geometry.

We have also installed water level monitoring well fields along some of the proposed restoration and control sites to measure the anticipated changes in floodplain groundwater levels upstream and downstream of the restoration structures. Automatic water level recorders/temperature monitors have been installed in the wells. In spring of 2007 we will also install temperature data loggers within the restored and control reaches, which will remain in place before, during and after completion of the restoration project. In addition, we plan to conduct an aerial survey of longitudinal stream temperature profile of Bridge Creek using Thermal Infrared Imagery (TIR) approximately every 5 yrs. A TIR survey was conducted in Murderers Creek in 2003 and 2004. This information provides high resolution of spatial temperature patterns. Such information can identify areas of spring water influence, the impacts of down-welling associated with beaver dams and changes in channel morphometry. This imagery can be used to as an explanatory variable to describe spatial patterns in fish distribution and growth rates. In addition, this spatial depiction of temperature can be used to interpolate between temperature data loggers, which are required to explain temporal patterns in temperature.

At the mouth of Bridge and Murderers Creeks there are gauging stations operated by the USGS. Near Bridge Creek, there is a weather station operated by Oregon Department of Transportation. We have a weather station that we will install and maintain in the Murderers Creek basin.

We will describe reach characteristics, riparian conditions, identifying habitat unit types, and for quantifying the amount of large woody debris using the methods employed by ODFW in their habitat inventory of the John Day subbasin to ensure data compatibility. The methods and indicator variables collected with this protocol can be viewed at http://osu.orst.edu/Dept/ODFW/freshwater/inventory/pdffiles/habmethod.pdf.

The variables described are indicators of habitat structure, sediment supply and quality, riparian forest connectivity and health, and in-stream habitat complexity. The specific attributes include but are not constrained to:

- Density of woody debris pieces (> 3 m length, >0.15 m diameter)
- Density of woody debris volume (> 3 m length, >0.15 m diameter)
- Density of key woody debris pieces (>10 m length, >0.6 m diameter)
- Density of wood jams (groupings of more than 4 wood pieces)
- Density of deep pools (pools >1 m in depth)
- Percent pool area
- Density of riparian vegetation (>0.5 m DBH) within 30 m of the stream channel
- Percent of channel shading (percent of 180 degrees)
- Percent of substrate area with fine sediments (<2 mm) in riffle units
- Percent of substrate area with gravel (2-64 mm) in riffle units

While these attributes do not describe all of the conditions necessary for high quality salmonid habitat, they do describe important attributes of habitat structure within and adjacent to the stream channel. The attributes are also indicative of streamside and upland processes. Based on the results of the John Day habitat protocol comparison coordinated through ISEMP and PNAMP, habitat monitoring protocols used in this study are subject to change. Habitat surveys will occur every other year and will be conducted across 1-km transects within each geomorphic used to describe treatment and control reaches.

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Appendix 1. Overview of Incision in the Columbia River Basin

Channel incision is a common occurrence in stream channels throughout the semi-arid regions of the interior Columbia River basin, where a fragile balance between climate, vegetation and geology makes the vertical stability of channels highly vulnerable to changes in hillslope erosion, stream discharge and loss of instream retention elements (Cooke and Reeves, 1976; Welcher, 1993; Peacock, 1994). We define incision as a rapid downcutting and lowering of the stream bed such that it reduces the frequency and duration of flooding onto the adjacent floodplain (sensu Leopold et al., 1964). Incision is a common response of streams to land use changes throughout much of the semi-arid regions of the American West and in other regions of North America, Africa, Australia, Europe, Asia, the Middle East and South America (Cooke and Reeves, 1976; Schumm et al., 1984; Nagle, 1993; Prosser et al., 1994; Simon et al., 1995; Vandekerckhove et al., 2000).

Incision has degraded instream and riparian habitat throughout the Columbia River basin, suggesting that restoration of such streams would benefit numerous species. Of particular interest is improving habitat for salmonids because many of the Columbia River stocks are listed under the United States Endangered Species Act. Many streams in the Columbia River basin that historically supported salmon no longer do so, and that habitat conditions are severely degraded in these incised streams (Nehlsen et al., 1991; Elmore et al., 1994; Wissmar, 1994). Incision can dramatically affect stream habitat for salmon and other fishes by the lowering of stream-adjacent water tables and the subsequent loss of riparian vegetation. The loss of above-ground vegetation reduces shading and organic inputs to the stream (Brown and Krygiier, 1970; Kiffney et al., 2000), while the loss of below-ground roots increases the erodibility of stream banks (Smith, 1976). The lowered water tables also directly impact the stream by reducing groundwater inputs to the stream. This is a significant concern in semi-arid regions such as in our study area because many streams have incised to bedrock and therefore the water table is at or near the bedrock and there is little opportunity for water to be stored in the alluvium. As a result, many incised streams cease flowing or have substantially reduced flows in the summer because there is no baseflow provided by the alluvial aquifer (Elmore and Beschta 1987). The loss of cool groundwater inputs also leads to increased summer stream temperatures (Poole and Berman, 2001). Further, incised streams rarely access their floodplains, high flows are concentrated within the incised channel, and fish have no access to slow-water refugia during floods (Harvey and Watson, 1986; Elmore and Beschta, 1987; Shields et al., 1995). In contrast numerous studies suggest that when local water tables of incised streams are raised, usually through the construction of beaver dams or small human-made dams, flows increase and intermittent streams become perennial (Reviewed in Ponce and Lindquist, 1990; Pollock et al., 2003).

The historical record suggests that numerous streams in the semi-arid region of the interior Columbia River basin once contained narrow, deep and gently meandering channels lined with dense riparian forests of cottonwoods Populus, willows Salix and/or sedges Carex, numerous beaver Castor canadensis dams (which are generally constructed out of numerous pieces of small diameter (1-4 cm) wood and mud), abundant and easily accessible off-channel habitat on the floodplain, and good flow and cool temperatures throughout most of the year (Buckley, 1992; Wissmar et al., 1994). Today many of these same streams are incised and contain little or no riparian vegetation or beaver dams. Stream temperatures are high and flow is ephemeral (Elmore and Beschta, 1987; Buckley, 1992; Peacock, 1994; CBMRC, 2005).

Land use change, climate change, or localized high intensity rainfall can cause channel incision, either by increasing the tractive force of water, or by decreasing the resistance of the stream bed (Cooke and Reeves, 1976). Within the Columbia River basin, the exact mechanism that caused widespread channel incision remains uncertain, although its timing almost invariably followed the widespread trapping of beaver and the onset of intensive sheep and cattle grazing in the mid 19th and early 20th centuries (Russell, 1905; Buckley, 1992; Peacock, 1994). In other semi-arid regions, aggradation (recovery from incision) has been observed when grazing practices and riparian land uses are altered to allow the re-establishment of riparian vegetation (Zierholz et al., 2001). Aggradation has also been observed to occur where beaver are able to build dams on streams (Scheffer, 1938; Butler and Malanson, 1995; McCullough et al., 2005). This suggests that recovery will occur when natural processes are allowed to operate. However, the time frames for recovery may range from decades to centuries. Recovery rates are related to both the quantity of sediment entering a channel and the ability of the channel to retain that sediment.

Recovery of incised streams has both a physical and biological component, though the two are interdependent. Physical recovery includes both the geomorphic and hydrologic changes that occur as a channel aggrades, while biological recovery includes the changes in riparian vegetation and instream biota that can either initiate or result from physical recovery. Much of the literature examining incised streams has focused on the changing geomorphic characteristics of such streams as they cycle through stable, incising and aggrading states (Leopold et al., 1964; Schumm et al., 1984; Darby and Simon, 1999). A general conceptual model has emerged regarding the channel evolution of incising streams (Figure 1). The model has numerous variants, but most include: A) a sequence of relative stability followed by B) rapid downcutting such that the stream is isolated from its floodplain, C) an increased stream width-to-depth ratio, a decrease in stream sinuosity and extensive widening of the incised trench, which eventually leads to D) a stream at a lower base level and a lower longitudinal slope, with a new inset floodplain that develops a more sinuous planform and lower width-to-depth ratio, then E) slow, long-term aggradation of the streambed and inset floodplain that F) may or may not reach the level and the longitudinal gradient of the former floodplain before a new cycle of incision begins. Because the incision phase is rapid and causes dramatic physical and ecological changes, research efforts have focused on understanding causes of incision, to what extent they are the result of land use practices versus a natural phenomenon, and how future incision can be prevented (Schumm et al., 1984; Darby and Simon, 1999). Less attention has been focused on factors influencing the post-incision phases and in particular the factors that might influence aggradation rates (but see Shields et al., 1999). Generally, it has been assumed that aggradation of incised streams is a slow process that operates on a multi-century timeframe, and that extensive widening of the incision trench must occur prior to aggradation (Leopold et al., 1964; Schumm et al., 1984; Rosgen, 1996). However, such assumptions are based almost entirely on the physical principles of sediment transport in fluvial systems, and do not include the effects of large wood, beaver dams (i.e. small wood) or riparian vegetation on sediment transport and deposition, and the modification of fluvial landforms. Nonetheless, the channel evolution model illustrated in Figure 1 provides a framework for understanding the sequence of geomorphic changes that might be expected to occur following incision and how aggradation rates might be altered by large wood, live vegetation or beaver dams.

Live vegetation, particularly dense, emergent graminoids such as sedges have been shown to effectively remove suspended sediment from water columns, primarily by creating a low velocity zone near the stream bed, which allows fine-grained material to settle out of suspension (Elliot, 2000; Braskerud, 2001; Carollo et al., 2002). Establishment of emergent vegetation following the cessation of cattle grazing has been implicated as an important prerequisite for aggradation of incised streams in the semi-arid regions of Australia (Zierholz et al., 2001). Similarly, beaver affect sediment transport when they dam small streams by weaving together numerous small pieces of wood and packing the interstices with mud (Morgan, 1986). The dams create low velocity stream reaches where sediment can drop from suspension. Additionally, they often raise the water level such that it permanently floods the adjacent floodplain or low terrace, thus creating a large shallow littoral zone suitable for the establishment of emergent and other riparian vegetation (Pastor et al., 1993). Thus beaver dams should affect sediment transport by directly influencing stream velocities, and indirectly by creating an environment conducive to the establishment of emergent vegetation that traps sediment. The geomorphic effects of beaver dams has been documented (reviewed by Gurnell, 1998; Pollock et al., 2003), though few studies have examined aggradation rates and only one has done so in an incised stream (McCullough et al., 2005). Butler and Malanson (1995) estimated sedimentation rates of 0.02-0.28 $m \bullet yr^{-1}$ above 4 beaver dams in Glacier National Park, Montana, while Meentemeyer and Butler (1999) observed average sediment depth of 0.28 m in 5 ponds $\leq$ 5 yrs old (i.e. a minimum aggradation rate of 0.06 $m \bullet yr^{-1}$), in Glacier National Park, Montana, while Scheffer (1938) observed aggradation of 0.55 m over a two year period on a small tributary to the Columbia River in eastern Washington. Naiman et al. (1986) estimated that 3.2 x 10^6 m^3 of sediment were stored behind all the beaver dams in 2^{nd}-4^{th} order streams in their study area in Quebec. They calculated that if this sediment were distributed evenly across all the streambeds, it would raise them by 42 cm. McCullough et al., 2005) studied beaver colonization of an incised stream in Nebraska and found that in a reach where beaver had been established for 12 years, stream bed aggradation averaged 0.65 m.

Field observations of small incised streams within the Columbia River basin suggests that incision depths typically range from 1-2 m, less frequently up to 5 m and in some extreme cases may incise as much as 20 m (e.g. see Peacock 1994). The aggradation rates behind beaver dams reported in the literature suggest that where beaver dams are present in incised streams, aggradation may occur at a rate sufficient to reconnect a stream to its former floodplain on decadal time scales, thus increasing projected rates of recovery by an order of magnitude or greater over recovery estimates when it is assumed no beaver dams are present (e.g. see Rosgen, 1994).

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Appendix 2. Rationale for using Bridge Creek as an Intensely Monitored Watershed

A recent study provided a synthesis on over 37,000 stream restoration actions that have occurred throughout the U.S. with highest density found in the Pacific Northwest (Bernhardt et al. 2005). Over 3 billion dollars have been spent on habitat restoration projects for salmonids in the Columbia River Basin alone (GAO 2002). Bernhardt et al. (2005) found that less 10% of these projects had any associated assessments or monitoring, with the majority of this focused on implementation monitoring. Restoration efforts are rarely coupled with effectiveness monitoring, resulting in a lack of consensus as to which restoration actions are most effective (Reeves et al. 1991; Kondolf 1995). Projects that have had been monitored for effectiveness often cannot demonstrate a benefit to the target population (Roni et al. 2002; Bernhardt et al. 2005; Roni 2005). Difficulty in demonstrating project success likely stems from: 1) imprecise monitoring protocols 2) lack of pre-project information (Reeve et al. 2006) 3) not monitoring for a long enough time period to observe full response (Kondolf 1995) 4) not accounting for other changes, such as fishing pressure (Thompson 2006) 5) monitoring single actions that produce effect sizes too small to accurately be detect (Reeve et al. 2006) 6) lack of powerful experimental designs (e.g. BACI design; Roni et al. 2005), or 7) projects were ineffective because they did not address the proper limiting factors (Roper et al. 1997). Evaluating whole watershed responses to large scale restoration in an experimental fashion has been suggested as a means to overcome many of these problems (Roni et al. 2002; Bilby et al. 2005; Roni et al. 2005; Reeve et al. 2006).

Ecosystem experiments are arguably the most direct method available for predicting a population or environmental response to management (Carpenter et al. 1995). Ecosystem scale experiments have contributed greatly to our understanding of ecological processes within watersheds (Likens et al. 1970; Wright et al. 1993; Hartman et al. 1996), and results from many of these studies have led to changes in management strategies (Likens et al. 1978; Wright et al. 1993; Hartman et al. 1996). However, generalization beyond a single system requires knowledge of mechanistic interactions or multiple ecosystem studies (Carpenter et. al. 1995).

Since ecosystem experiments have led to great insights into the mechanisms regulating populations and are conducted at the appropriate scale to assess management implications to populations, Intensively Monitored Watershed (IMW) studies have been initiated throughout the region to evaluate population level responses to large-scale restoration efforts (Bilby et al. 2004; Bilby et al. 2005; PNAMP 2005). The goal is to develop a network of IMWs to assess limiting factors, develop actions aimed at restoring ecosystem processes, and evaluate the effectiveness of different actions or a suite of actions on fish populations across a range of watershed types. If IMW studies cover enough ecotypes, then the results of these intensive studies can form the expectations of the types of impacts certain restoration actions can have in watersheds throughout the Columbia River Basin. Experimental designs and statistical analyses for maximizing the power of these types of large-scale experiments are well documented (Carpenter 1990; Stewart-Oaten and Bence 2001; Roni et al. 2005). If these large scale manipulations with intensive monitoring do not result in detectable differences then it is unlikely that smaller scale and less intensively monitored projects ever will.

In additional to being a powerful design to detect impacts, IMWs will provide additional information to inform monitoring programs developed for the Federal RME program. For example, instream PIT-tag antennas appear to be a promising tool for providing vital rates of stream fishes. However, several technical problems still exists in the implementation of this technology such as reliable power sources, acceptable tag read ranges, and ability to withstand high flows. In addition, several design and analytical challenges in processing this information (e.g. Cormak-Jolly-Seber vs. robust design Barker models) need to be address. Other monitoring techniques can be compared and cross calibrated, such as ODFW habitat monitoring protocols and LiDAR approaches. The ability of this information to reveal small watershed scale changes and relationships with quality population level information also will be tested. This higher detailed information will also provide unique opportunity to validate and calibrate several analytical models used in limiting factors analyses or restoration planning (e.g. EDT and SHIRAZ). Finally, the information in IMWs will provide status and trend information at a higher level of detail than subbasin monitoring programs, thus relieving these programs from monitoring these watersheds and allowing for either a greater effort or less funding in the remaining subbasin.

Appendix 3.Timeline for Bridge Creek IMW Restoration Project 2005-2009

Date	Activity	Where	Design	Notes
2005				
Jan	Recapture PIT tag fish. Tag non-tagged fish.	3 sentinel sites on Murderers	Night snorkeling and dipnetting (Tattam 06). 2-person crew.	Part of South Fork IMW (Bouwes 06)
May	Comparison of fish densities across reaches	Beaver ponds complexes with control reaches. Two pond/control reaches in Bridge Creek, one in Gable Creek	Seining protocol (Tattam 06). 3-person crew. Abundance based on mark-recapture of fin clipped fish.	No PIT tags used
May-Jun	Recapture PIT tag fish. Tag non-tagged fish.	3 sentinel sites on Murderers	Seining protocol (Tattam 06). 3-person crew. PIT tag antenna used to monitor movement.	Part of South Fork IMW (Bouwes 06)
Jun	Habitat and snorkel survey	Lower 13 miles of Murderers Cr	Snorkel counts of all fish species. Habitat monitoring using modified Hankin-Reeves. Complete census	Part of South Fork IMW (Bouwes 06)
Sept	LiDAR survey of Bridge and Murderers Creek	Bridge Creek and the lower 13 miles of Murderers Creek	Aerial census	Part of South Fork IMW (Bouwes 06)
Sep	Recapture PIT tag fish. Tag non-tagged fish.	3 sentinel sites on Murderers	Seining protocol (Tattam 06). 3-person crew. PIT tag antenna used to monitor movement.	Part of South Fork IMW (Bouwes 06)
Sept	Comparison of fish densities across reaches	Beaver ponds complexes with control reaches. Two pond/control reaches in Bridge Creek, one in Gable Creek	Seining protocol (Tattam 06). 3-person crew. Abundance based on mark-recapture of fin clipped fish.	No PIT tags used.
2006				
Jan	Recapture PIT tag fish. Tag non-tagged fish.	3 sentinel sites on Murderers	Night snorkeling and dipnetting (Tattam 06). 2-person crew.	Part of South Fork IMW (Bouwes 06)
Jan	Comparison of fish densities across reaches	Beaver ponds complexes with control reaches. Two pond/control reaches in Bridge Creek, one in Gable Creek	Night snorkeling and dipnetting (Tattam 06). 2 person crew. Abundance based on mark-recapture of fin clipped fish.	No PIT tags used
May	Prioritize mainstem Bridge Creek reaches for restoration	Bridge Creek	Based on LiDAR, GIS, aerial photographs and fieldwork. Based primarily on geomorphic features	Draft completed
May	Invertebrate sampling	2 reaches on Bridge Creek, Gable Creek, Bear Creek, 3 sentinel sites on Murderers Cr	24 hr drift net samples, and benthic samples, conducted by Weber	
May	PIT tag fish	3 sentinel sites Murderer's, 2 treatment/control reaches Bridge Creek, and a treatment/control on each tributary.	Seining protocol (Tattam 06). 3-person crew. PIT tag antenna used to monitor movement.	PIT tagging of juv. *O. mykiss. Some SM bass tagged.*
July	Invertebrate sampling	3 reaches on Bridge Creek, Gable Creek, Bear Creek, 3 sentinel sites on Murderers Cr	24 hr drift net samples, and benthic samples, conducted by Weber	
Aug	Install monitoring wells at 3 priority restoration sites	Installed at 3 sites on Bridge Creek	Three rows of wells perpendicular to channel spaced 50 m apart	may want to install at more sites
Sep	Recapture PIT tag fish. Tag non-tagged fish.	3 sentinel sites Murderer's, 2 treatment/control reaches Bridge Creek, and a treatment/control on each tributary.	Seining protocol (Tattam 06). 3-person crew. PIT tag antenna used to monitor movement.	Completed for 2006. PIT tagging of juv. O. mykiss
Sept	Invertebrate sampling	3 reaches on Bridge Creek, Gable Creek, Bear Creek, 3 sentinel sites on Murderers Cr	24 hr drift net samples, and benthic samples, conducted by Weber	
2007				
Jan-Feb	Recapture PIT tag fish. Tag non-tagged fish.	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Night snorkeling and dipnetting (Tattam 06). 2-person crew. Barker Robust design of 3 consecutive days per reach	Completed for 2006. PIT tagging of juv. O. mykiss
Feb	Complete Geodatabase		Oakley/Reentmeester design	
Feb	Initiate permitting process for pilot restoration project on 500 m of stream	Bridge Creek	1-2 starter dams, 6-12 post-pile fences located in Owens ranch section of Bridge	Permits needed. BiOp exemption?
Mar	Install Juvenile/Adult weir traps	mouth of Bridge and Murderers Cks	Bouwes design	Permits needed, may cause delay
Mar-June	Operate and maintain juvenile/adult weir traps.	Bridge and Murderers Cks	Operate every 3rd day at beginning and end of migration distribution (5th/95th percentiles), and everyday during main migration period	
Mar	Geomorphic characterization	Bridge and Murderers Cks	Pollock design	
April	Adult steelhead redd and carcass surveys on Bridge and Murderer's Cks	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Per ODFW protocol. Conduct census, then 10 random 1km reaches two weeks later.	Coordinate w/ODFW. Possible turbidity issues
April	Design long-term data management system for Bridge Ck monitoring data	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Reentmeester/Volk design	include at a min: fish, monitoring wells, temp
May	Install instream temperature loggers	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	within each priority site.	use existing Onset loggers
May-Jun	Recapture PIT tag fish. Tag non-tagged fish.	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Seining protocol (Tattam 06). 3-person crew. Barker Robust design of 3 consecutive days per reach. PIT tag antenna used to monitor movement.	Annual NOAA permit renewal. Increase effort over last year.
Jun	Install PIT tag detectors	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Earl Prentice Design. Double readers at each site to get directionality.	HPA, BLM other? Permits, may cause delay. Need LO permission on Bear Ck
July	Invertebrate sampling	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	24 hr drift net samples, and benthic samples, conducted by Weber	
July	Conduct FLIR flights	Bridge Creek, Gable Creek, Bear Creek	Complete aerial census, conducted by Watershed Sciences	

Date	Activity	Where	Design	Notes
July-Sept	Stream habitat surveys	Bridge Creek, Gable Creek, Bear Creek	Per ODFW protocols. 2 man crew. Conduct over random 1 km transect within each treatment and control reach.	
Sep	Physical installation of pilot restoration structures	Bridge Cr	1-2 starter dams, 6-12 post-pile fences. Install s-dam w/ excavator, use pile-driver	Contract out or get volunteers. use junipers?
Sep	Transplant 1-2 beaver families	Bridge Cr	Per protocol of Wyoming Game and Fish	Work w/ODFW
Sep	Provide wood for dam-building	Bridge Cr	Deposit directly in pond, feed 1-2x/yr in Sep and Oct	Cutting permit needed from USFS/BLM
Sep	Recapture PIT tag fish. Tag non-tagged fish.	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Seining protocol (Tattam 06). 3-person crew. Barker Robust design of 3 consecutive days per reach. PIT tag antenna used to monitor movement.	Annual NOAA permit renewal. Increase effort over last year.
Oct-Jan	Operate and maintain juvenile/adult weir traps.	Bridge and Murderers Cks	Operate every 3rd day at beginning and end of migration distribution (5th/95th percentiles), and everyday during main migration period	
All year	maintain, repair and analyze data from PIT tag detectors	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr		
2008				
Jan	Recapture PIT tag fish. Tag non-tagged fish.	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Night snorkeling and dipnetting (Tattam 06). 2-person crew. Barker Robust design of 3 consecutive days per reach	Annual NOAA permit renewal. Increase effort over last year.
March	Riparian tree planting and fencing	Bridge Cr	Cottonwood stakes in contact with the water table, wire cages/fencing	
Mar-June	Operate and maintain juvenile/adult weir traps.	Bridge and Murderers Cks	Operate every 3rd day at beginning and end of migration distribution (5th/95th percentiles), and everyday during main migration period	
April	Adult steelhead redd and carcass surveys on Bridge and Murderer's Cks	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Per ODFW protocol. Conduct census, then 10 random 1km reaches two weeks later.	Coordinate w/ODFW. Possible turbidity issues
May-Jun	Recapture PIT tag fish. Tag non-tagged fish.	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Seining protocol (Tattam 06). 3-person crew. Barker Robust design of 3 consecutive days per reach. PIT tag antenna used to monitor movement.	Annual NOAA permit renewal. Increase effort over last year.
Jun-Aug	Construct 8 more sets of beaver dam enhancement structures	Bridge Cr	see previous notes	Spacing @ 500m for a total of 4 km in 2008.
July	Invertebrate sampling	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	24 hr drift net samples, and benthic samples, conducted by Weber	
Sep	Recapture PIT tag fish. Tag non-tagged fish.	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Seining protocol (Tattam 06). 3-person crew. Barker Robust design of 3 consecutive days per reach. PIT tag antenna used to monitor movement.	Annual NOAA permit renewal. Increase effort over last year.
Sep-Oct	Transplant eight beaver families/provide wood for dam-building	Bridge Cr	see previous notes	see previous notes
Oct-Jan	Operate and maintain juvenile/adult weir traps. Continuously	Bridge and Murderers Cks	Operate every 3rd day at beginning and end of migration distribution (5th/95th percentiles), and everyday during main migration period	
All year	maintain, repair and analyze data from PIT tag detectors	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr		
2009				
Jan	Recapture PIT tag fish. Tag non-tagged fish.	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Night snorkeling and dipnetting (Tattam 06). 2-person crew. Barker Robust design of 3 consecutive days per reach	
March	Riparian tree planting and fencing	Bridge Cr	Cottonwood stakes in contact with the water table, wire cages/fencing	
April	Adult steelhead redd and carcass surveys on Bridge and Murderer's Cks	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Per ODFW protocol. Conduct census, then 10 random 1km reaches two weeks later.	Coordinate w/ODFW. Possible turbidity issues
Mar-June	Operate and maintain juvenile/adult weir traps.	Bridge and Murderers Cks	Operate every 3rd day at beginning and end of migration distribution (5th/95th percentiles), and everyday during main migration period	
May-Jun	Recapture PIT tag fish. Tag non-tagged fish.	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Seining protocol (Tattam 06). 3-person crew. Barker Robust design of 3 consecutive days per reach. PIT tag antenna used to monitor movement.	Annual NOAA permit renewal
July	Invertebrate sampling	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	24 hr drift net samples, and benthic samples	
July-Sept	Stream habitat surveys	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Per ODFW protocols. 2 man crew. Conduct over random 1 km transect within each treatment and control reach.	
Jun-Aug	Construct 16 more sets of beaver dam enhancement structures	Bridge Cr	see previous notes	Spacing @ 500m for a total of 8 km in 2009.
Sep-Oct	Transplant eight beaver families/provide wood for dam-building	Bridge Cr	see previous notes	see previous notes
Sep	Recapture PIT tag fish. Tag non-tagged fish.	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr	Seining protocol (Tattam 06). 3-person crew. Barker Robust design of 3 consecutive days per reach. PIT tag antenna used to monitor movement.	
Oct-Jan	Operate and maintain juvenile/adult weir traps. Continuously	Bridge and Murderers Cks	Operate every 3rd day at beginning and end of migration distribution (5th/95th percentiles), and everyday during main migration period	
All year	maintain, repair and analyze data from PIT tag detectors	Bridge Creek, Gable Creek, Bear Creek, Murderers Cr		